that there was no increase in nitrogen during all the weeks the Algæ had been flourishing, and that accordingly no iota of the stream of free nitrogen which had been constantly passing through the apparatus had been "fixed." So far, then, the first Alga which had been put to the test of experiment showed itself incapable of utilising atmospheric nitrogen.

Kossowitch now turned to fresh experiments, choosing algal cultures of sometimes one, sometimes several species taken together; to all of these he added simultaneously soil-bacteria of mixed sorts. The apparatus employed was very nearly the same as that above described. In these experiments he desired to test the supposition of Berthelot and Winogradsky, who considered the presence of certain organic substances to be favourable to the fixation of nitrogen; he accordingly arranged his experiments in five pairs, both members of each couple having identical conditions, except that in the one a small quantity of sugar (dextrose) was added to the nutritive solution, whilst in the other no organic compound was present. One set was arranged with Cystococcus and soil-bacteria, and the results obtained showed that in the absence of organic materials a small but yet noticeable increase in the nitrogen of the system had taken place (from 2·6 mg. to 3·1 mg.) Where sugar had been previously added, however, there were three times as much nitrogen after the experiment as before. In a second pair of cultures the Alga Stichococcus and certain bacteria were used, but here in no case, either with or without sugar, was there any increase in nitrogen. This shows that Stichococcus has in itself no power of nitrogen fixation.

Another couple contained a mixture of several Algæ, Nostoc, Cylindrospermum, &c., and certain soil-bacteria. In this instance a very large fixation of nitrogen took place, both where sugar was present and where not; in fact, in the former case the nitrogen was increased more than nine-fold.

All these observations shed much light upon the question of the relations existing between Algæ, micro-organisms, and atmospheric nitrogen. They show:—

(1) That at least two Algæ—Cystococcus and Stichococcus—possess no "fixing" powers in themselves.

(2) That many Algæ, taken together with certain micro-organisms of the soil, do possess the power of assimilating atmospheric nitrogen.

(3) That this power is much increased by the addition of such organic substances as sugar.

It should be noticed that among the ten cultures used in the second set of experiments, only two contained definitely isolated algal species, viz. the cases of the two cultures of Cystococcus and soil-bacteria.

It was just in this instance, moreover, that it had been shown that the Alga itself had no capacity for fixing atmospheric nitrogen. Accordingly, there could be little doubt that it was through the agency of the micro-organisms that the "fixation" had taken place in these latter cultures.

The experiments of Laurent and Schloesing had shown that if in a culture of Algæ and bacteria endowed with "fixing" powers, the Algæ were destroyed, the bacteria lost partly, if not entirely, this capacity, which the mixture had possessed. This pointed clearly to the fact that there was some close relationship existing between the Algæ and micro-organisms.

There are many facts which seem to indicate the nature of this relationship.

Berthelot found that the nitrification of the soil only took place as long as organic compounds were present; if these were exhausted, the nitrifying process ceased. Gautier and Drouin also showed the importance which organic compounds have with respect to nitrification. Kossowitsch's own experiments, in which the advantage of adding sugar to the culture was shown, also point in the same direction.

From such observations as these, Kossowitsch concludes that the relationship which the Algæ bear to the micro-organisms is one connected with the organic food supply of these latter; he thinks that the Algæ, furnished with nitrogen by the bacteria, assimilate carbohydrate material, part of which goes to their own maintenance, but part also to that of the micro-organisms. It is, therefore, in his belief, an instance of symbiosis in which each supplies the wants of the other. There are many facts, partly the result of his own observations, partly the result of those of others, which uphold this view. If the mixed culture be placed in the light, there is a far more noticeable nitrogen increase than when in darkness. Again, if a rich supply of carbon dioxide gas be provided, this is marked by a decided rise in nitrogen-fixing powers. Both these conditions are such as are known to influence carbohydrate assimilation in chlorophyll-containing organisms; but all experience is antagonistic to the view that light should be beneficial to the vital activity of the bacteria, and there are only one or two exceptional instances (Nitromonas, &c.) in which carbon dioxide can be directly assimilated by these micro-organisms.

Moreover, in the cases where the bacteria are brought into immediate contact with the Alga, as in those species of Algæ which are enveloped in a gelatinous covering wherein the micro-organisms become embedded, nitrogen fixation appears to be greatly aided, and the addition of sugar to the culture has no such marked effect as in the instances where non-gelatinous Algæ are employed. The explanation of this seems to be that the bacteria embedded in the gelatinous sheath are amply provided with carbohydrate food without the addition of sugar, which, therefore, comes more or less as a superfluity.

All this seems to justify Kossowitsch's view of the part played by the Algæ in the fixation of nitrogen; it appears to show that they have an indirect, but none the less important, influence upon the process.

This is roughly the extent of Kossowitsch's article; it has been impossible to give here its details, the bare outlines of his researches could alone be mentioned, but it is hoped that sufficient has been said to show the importance of his work, perhaps even to indicate the interest which every page of his memoir possesses, dealing as it does with one of the most fascinating branches of vegetable physiology.

Rudolf Beer.

THE COMMERCIAL SYNTHESIS OF ILLUMINATING HYDROCARBONS.[1]

THE direct combination of carbon and hydrogen in the electric arc is a true case of synthesis, and if we could form acetylene in this way in sufficiently large quantities, it would be perfectly easy to build up from the acetylene the whole of the other hydrocarbons which can be used for illuminating purposes. For instance, if acetylene be passed through a tube heated to just visible redness, it is rapidly and readily converted into benzol; at a higher temperature naphthalene is produced, whilst by the action of nascent hydrogen on acetylene, ethylene and ethane can be built up. From the benzol we readily derive aniline, and the whole of that magnificent series of colouring matters which have gladdened the heart of the fair portion of the community during the past five-and-twenty years, whilst the ethylene produced from acetylene can be readily converted into ethyl alcohol, by consecutively treating it with sulphuric acid and water, and from the alcohol, again, an enormous number of other organic substances can be produced, so that acetylene can, without exaggeration, be looked upon as one of the great keystones of the organic edifice, and, given a cheap and easy method of preparing it, it is hardly possible to foresee the results which will be ultimately produced.

In 1836, it was found that when making potassium, by distillation from potassic carbonate and carbon, small quantities of a bye-product, consisting of a compound of potassium and carbon, was produced, and that this was decomposed by water with liberation of acetylene; whilst Wöhler, by fusing an alloy of zinc and calcium with carbon, made calcic carbide, and used it as a source from which to obtain acetylene by the action of water.

Nothing more was done until 1892, when Macquenne prepared barium carbide by heating at a high temperature a mixture of barium carbonate, powdered magnesium, and charcoal, the resulting mass evolving acetylene, when treated with water; whilst, still later, Travers made calcic carbide by heating together calcic chloride, carbon, and sodium. None of these processes, however, gave any commercial promise, as the costly nature of the potassium, sodium, magnesium, or calcium-zinc alloy which had to be used, made the acetylene produced from the carbide too expensive.

Whilst working with an electric furnace, and endeavouring by its aid to form an alloy of calcium from some of its compounds, Mr. T. L. Willson noticed that a mixture containing lime and powdered anthracite, under the influence of the tem-

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[1] Abstract of a paper by Prof. Vivian B. Lewes, read before the Society of Arts, Wednesday, January 16.

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perature of the arc, fused down to a heavy semi-metallic mass, which having been examined, and found not to be the substance sought, was thrown into a bucket containing water, with the result that violent effervescence of the water marked the rapid evolution of a gas, the overwhelming odour of which enforced attention to its presence, and which, on the application of a light, burnt with a smoky, but luminous flame.

Investigation into the cause of this phenomenon soon showed that in a properly constructed electric furnace, finely ground up chalk or lime, mixed with powdered carbon in any form, whether it were charcoal, anthracite, coke, coal, or graphite, can be fused with the formation of a compound known as calcic carbide, containing 40 parts by weight of the element calcium, the basis of lime, and 24 parts by weight of carbon, and that, on the addition to this of water, a double decomposition takes place, the oxygen of the water combining with the calcium of the calcic carbide to form calcic oxide or lime, whilst the hydrogen unites with the carbon of the calcic carbide to form acetylene, the cost of the gas so produced bringing it not only within the range of commercial possibilities for use *per se*, but also the building up from it of a host of other compounds, whilst the production of the calcic carbide from chalk and from any form of carbon, renders us practically independent of coal and oil, and places in our hands the prime factor by which nature in all probability produces those great underground storehouses of liquid fuel upon which the world is so largely drawing to-day.

Calcic carbide is a dark grey substance, having a specific gravity of 2·262, and, when pure, a pound of it will yield on decomposition 5·3 cubic feet of acetylene. Unless, however, it is quite fresh, or means have been taken to carefully protect it from air, the outer surface gets slightly acted upon by atmospheric moisture, so that in practice the yield would not exceed five cubic feet. The density and hardness of the mass, however, protects it to a great extent from atmospheric action, so that in lumps it does not deteriorate as fast as would be expected, but in the powdered condition it is rapidly acted upon.

The acetylene made from it, when analysed by absorption with bromine, the analysis being also checked by determining the amount present by precipitation of silver acetylide, gives 98 per cent. of acetylene and 2 per cent. of air, and traces of sulphuretted hydrogen, the presence of this impurity being due to traces of sulphate of lime—gypsum—in the chalk used for making it, and to pyrites in the coal employed.

Acetylene is a clear, colourless gas with an intensely penetrating odour which somewhat resembles garlic, its strong smell being a very great safeguard in its use, as the smallest leakage would be at once detected; indeed, so pungent is this odour, that it would be practically impossible to go into a room which contained any dangerous quantity of the gas.

This is an important point to remember, as the researches of Bistrow and Liebreich show that the gas is poisonous, combining with the hæmoglobin of the blood to form a compound similar to that produced by carbon monoxide; whilst the great danger of the latter gas is that having no smell, its presence is not detected until symptoms of poisoning begin to show themselves, so that no fear need be apprehended of danger from this source with acetylene.

Acetylene is soluble in water and most other liquids, and at ordinary temperature and pressure—60° F. and 30 inches of mercury—10 volumes of water will absorb 11 volumes of the gas; but as soon as the gas is dissolved, the water being saturated takes up no more. Water already saturated with coal-gas does not take up acetylene quite so readily, whilst the gas is practically insoluble in saturated brine—100 volumes of a saturated salt solution only dissolving 5 volumes of the gas. The gas is far more soluble in alcohol, which at normal temperature and pressure takes up six times its own volume of the acetylene, whilst 10 volumes of paraffin under the same conditions will absorb 26 volumes of the gas. It is a heavy gas, having a specific gravity of 0·91.

When a light is applied to acetylene, it burns with a luminous and intensely smoky flame, and when a mixture of one volume of acetylene with one volume of air is ignited in a cylinder, a dull red flame runs down the cylinder, leaving behind a mass of soot, and throwing out a dense black smoke. When acetylene is mixed with 1·25 times its own volume of air, the mixture begins to be slightly explosive, the explosive violence increasing until it reaches a maximum with about twelve times its volume of air, and gradually decreases in violence until, with a mixture of one volume of acetylene to twenty of air, it ceases to be explosive.

The gas can be condensed to a liquid by pressure, Andsell finding that it liquefied at a pressure of 21·5 atmospheres, at a temperature of 0° C., whilst Cailletet found that at 1° C. it required a pressure of 48 atmospheres, the first-named pressure being probably about the correct one. The liquid so produced is mobile, and highly refractive, and when sprayed into air, the conversion of the liquid into the gaseous condition absorbs so much heat that some of the escaping liquid is converted into a snow-like solid, which catches fire on applying a light to it, and burns until the solid is all converted into gas and is consumed.

In my researches upon the luminosity of flame, I have shown that all the hydrocarbons present in coal-gas and other luminous flames are converted by the baking action taking place in the inner non-luminous zone of the flame into acetylene before any luminosity is produced, and that it is the acetylene which by its rapid decomposition at 1200° C. provides the luminous flame with these carbon particles, which, being heated to incandescence by various causes, endow the flame with the power of emitting light. The acetylene, being in this way proved to be the cause of luminosity, one would expect that in this gas we have the most powerful of the gaseous hydrocarbon illuminants; and experiment at once shows that this is the case.

Owing to its intense richness, it can only be consumed in small flat flame burners, but under these conditions emits a light greater than that given by any other known gas, its illuminating value calculated to a consumption of 5 cubic feet an hour being no less than 240 candles.

Illuminating Power of Hydrocarbons for a Consumption of 5 cubic feet of Gas.

	Candles.
Methane	5·2
Ethane	35·7
Propane	56·7
Ethylene	70·0
Butylene	123·0
Acetylene	240·0

It is stated that the carbide can be made at about £4 a ton; and if this be so, it should have a great future, as a ton will yield 11,000 cubic feet of the gas. The lime left as a bye-product would be worth 10*s*. a ton, and the gas would cost at this rate 6*s*. 4½*d*. per 1000 cubic feet, and in illuminating value would be equal to London coal gas at 6*d*. a thousand. Its easy production would make it available for illuminating purposes in country houses, whilst its high illuminating value should make it useful for enriching poor coal gas.

CHEMICAL CHANGES BETWEEN SEA-WATER AND OCEANIC DEPOSITS.[1]

THE numerous analyses of sea-water by Forchhammer previous to 1865, and the later analyses by Dittmar, from samples collected during the *Challenger* Expedition, show that while the *salinity*—*i.e.* the amount of dissolved salts contained in 100 parts of sea-water—varies greatly in different regions of the ocean, still the composition of these dissolved salts—*i.e.* the ratio of the constituents of sea-salts—remains practically the same in all the superficial waters of the ocean. Consequently, it is only necessary to determine the chlorine in a definite weight of water to ascertain at once the respective quantities of the other salts present in the sample. Dittmar's examination of the *Challenger* waters has, however, shown that lime is slightly, although distinctly, more abundant in samples of sea-water collected in greater depths than in those samples collected nearer the surface of the ocean, and Dittmar's tables showing the difference between the chlorine calculated from the specific gravity and the chlorine found by analysis[2] point to differences in the composition of the sea-salts; but the observations are

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[1] Abstract of a Paper read before the Royal Society of Edinburgh on March 7, 1892, by Dr. John Murray and Robert Irvine, and published in *Trans.*, vol. xxxvii. part 2, No. 23.

[2] Dittmar, "*Challenger* Report on the Composition of Ocean Water," "Phys. Chem. *Chall.* Exp.," part 1, p. 43.

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